Captures of Boll Weevils (Coleoptera: Curculionidae) in Traps Associated with Different Habitats

D. W. SPURGEON AND J. R. RAULSTON[1]

USDA–ARS, Areawide Pest Management Research Unit, 2771 F&B Road, College Station, TX 77845

ABSTRACT Programs to eradicate the boll weevil, *Anthonomus grandis grandis* Boheman, from cotton, *Gossypium hirsutum* L., in the United States rely heavily on pheromone traps for monitoring weevil populations in both active and posteradication maintenance programs. Modifications to trapping protocols that increase trap effectiveness should contribute to this eradication effort. Between October 1996 and May 1997 and between September 1997 and April 1998, we compared trap effectiveness, indicated by the numbers of captured weevils, in relation to selected habitat types. Each study period was divided into fall, winter, and spring seasons. Traps were closely associated with seven habitat types, including four types with prominent erect vegetation (brush-lined irrigation canal, brush, sugarcane, and resaca or ox-bow lake) and three types with only low-growing or sparse erect vegetation (irrigation drainage canal, unimproved pasture, and fallow fields). Captures of male and female weevils were statistically similar regardless of season or trapping habitat. Although captures differed significantly among habitats, these differences varied among seasons. Trapping habitats with prominent vegetational features generally produced higher weekly captures of weevils than habitats lacking these features. Also, captures in traps associated with prominent vegetation indicated seasonal differences in weevil activity, with highest captures occurring during the fall. Traps associated with habitats lacking prominent vegetation did not statistically demonstrate seasonal differences. Our results indicate that immediate trap surroundings strongly influence the effectiveness of the boll weevil pheromone trap. These results also suggest that effectiveness of current trapping programs may be improved through purposeful association of traps with selected vegetational features.

KEY WORDS boll weevil, *Anthonomus grandis grandis*, pheromone trapping

Programs to eradicate the boll weevil, *Anthonomus grandis grandis* Boheman, from cotton, *Gossypium hirsutum* L., rely heavily on pheromone traps for population monitoring and detection (El-Lissy et al. 1997, Smith 1998). After active eradication programs, the pheromone trap remains the primary means of detecting weevil activity in maintenance programs. Thus, modifications to trapping protocols that result in improved detection or monitoring ability should assist in achieving and maintaining eradication.

Several investigators have reported increased captures of boll weevils in traps associated with wooded areas (Cross and Hardee 1968, Hardee et al. 1972, Roach et al. 1972). These authors generally assumed the increased captures resulted from the nearness of the traps to overwintering habitat of the boll weevil. Guerra and Garcia (1982) similarly observed increased captures of weevils in traps bordering wooded

areas in the Lower Rio Grande Valley of Texas. However, the overwintering habitats considered typical of temperate zones are not used extensively by the weevil in the subtropics (Graham et al. 1978, Rummel and Summy 1997). Thus, factors other than proximity of the traps to overwintering habitat were likely responsible for the observations of Guerra and Garcia (1982).

The Lower Rio Grande Valley of Texas is a production region characterized by moderately high sustained wind speeds. Sappington and Spurgeon (2000a) examined the influence of trap orientation (leeward and windward) to brush lines in that region. They found that brush lines moderated wind speeds, resulting in increased captures of weevils in leeward traps when wind speeds were >10 km/h. However, their study did not examine the influences of brush lines on captures of weevils in traps relative to captures in traps situated in more open settings, nor did it examine the potential influences of other common prominent vegetative features. Our objective was to examine the influences of several prominent vegetational features, typical of the Lower Rio Grande Valley, on trap captures of the boll weevil.
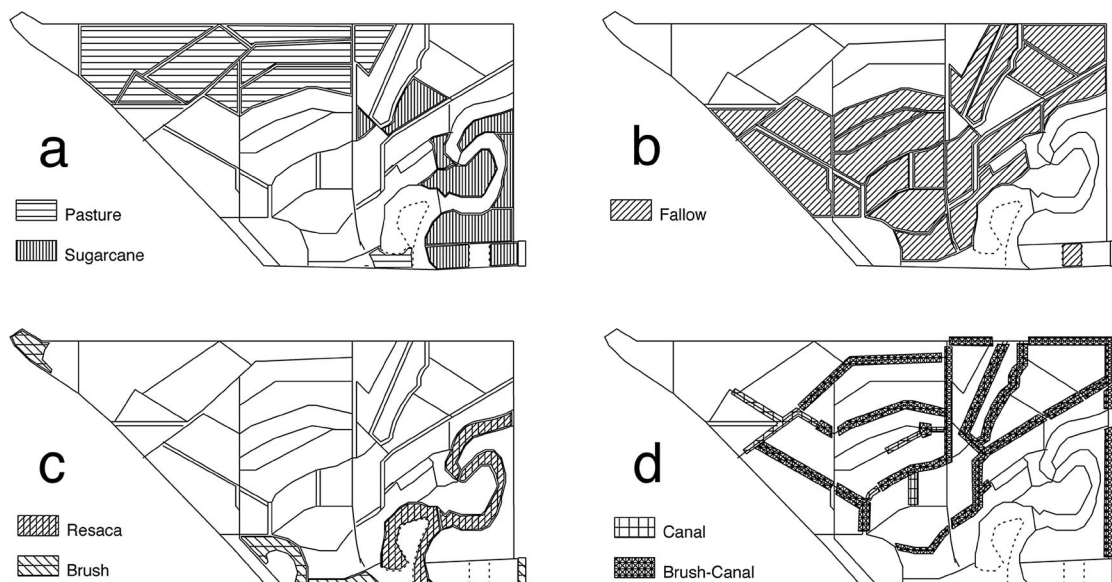
Fig. 1. Distribution of habitat types associated with boll weevil traps on Russell Plantation, San Benito, TX, from October 1996 to May 1997. (a) Unimproved pasture and sugarcane. (b) Fallow cropland. (c) Resaca (ox-bow lake) and native brush. (d) Irrigation drainage canal and brush-lined drainage canal.

Materials and Methods

Experimental Procedure. The study was conducted on the Russell Plantation, south of San Benito, TX (Fig. 1a–d). The plantation occupied a contiguous area of ≈1,500 ha, including ≈120 ha of cotton. The locations of cotton fields varied during the study, but they were distributed among other crops in fields designated as "fallow" in Fig. 1b. Cotton also was produced on surrounding land, generally within 0.5 km of the plantation. Because late-season weevils rapidly disperse from fields of destroyed cotton, trapping periods during both years were selected to minimize or avoid the influences of previous or subsequent cotton crops. The first study period was from 14 October 1996 to 5 May 1997 (29 wk), and the second study period was from 8 September 1997 to 6 April 1998 (30 wk). Thus, trapping studies were initiated well after harvest and the 1 September mandatory stalk destruction deadline and were terminated before the following crop (planted early to mid-March) began to produce substantial numbers of squares (flower buds). At the beginning of each study period a grid of standard Hercon Scout traps (Hercon Environmental, Emigsville, PA) was installed on the Plantation. Traps, each supported ≈1 m above ground on a stake of metal conduit, were placed at ≈80-m intervals along all accessible farm roads, turn rows, and fence lines. Each trap was baited with a standard 10-mg lure (Hercon Environmental, Emigsville, PA) containing grandlure. Lures were replaced every 2 wk. Each trap was assigned one of seven habitat types. These habitat types were based on the dominant vegetative feature immediately adjacent to the trap. Traps assigned to brushy habitat types were placed directly on the edge

of the habitat in small clearings of ≥2 m in diameter. These clearings were periodically maintained to ensure that weeds and other vegetation did not interfere with the traps.

Habitat types were designated as irrigation drainage canal (canal; 31 and 59 traps in first and second study periods, respectively), brush-lined canal (brush-canal; 239 and 204 traps), brush (40 and 35 traps), sugarcane (37 and 52 traps), unimproved pasture (pasture; 161 and 219 traps), fallow fields (fallow; 117 and 84 traps), and ox-bow lake (resaca; 106 and 104 traps in first and second study periods, respectively). Canals were earthen trenches typically 20–30 m across with only low-growing or sparse erect vegetation on their banks. These structures frequently contained surface water. Brush-canals were similar to canals except their banks were lined with a narrow stand of erect vegetation (native trees and shrubs but primarily *Prosopis* [mesquite] and *Acacia* spp.). Brush was wooded area populated by a dense stand of native trees and shrubs. The resaca habitat type was characterized by relatively wide (>50 m) ox-bow lake with a 10–15-m-wide border composed of native trees and shrubs. Predominant erect vegetation in both brush and resaca habitats included *Prosopis* and *Acacia* spp. as well as the evergreen *Ebenopsis ebano* (Berl.) Barneby & Grimes (Texas ebony). Sugarcane was commercial plantings of *Saccharum* spp. Pasture was primarily grasses, but some areas also were populated by sparse stands of *Prosopis* and *Acacia* spp. This habitat type differed from other habitats featuring brush in that the prominent erect vegetation was spatially diffuse and did not form a distinct border. Finally, the fallow habitat type was plowed croplands for most of both study periods

except for late spring, when these areas were planted to cotton; corn, *Zea mays* L.; or sorghum, *Sorghum bicolor* (L.) Moench. Figure 1a–d illustrates the physical arrangement of habitats in the first study period. Habitats were similarly arranged during the second study period except for an increase in the hectarage of sugarcane, the clearing of some brush-canal habitat, and increased access to interior portions of the pasture.

During the experiment, traps were checked weekly except when turn rows became impassable because of heavy rains. Because of the large number of traps, all traps could not be serviced on a single day. Rather, traps were divided into five groups, with each group being assigned to a separate day of the week. Captured weevils were collected into vials containing 70% isopropyl alcohol and transported to the laboratory where they were divided by sex using the method of Sappington and Spurgeon (2000b). Captures from traps that were knocked down, missing, obstructed by spider webs, or that were not accessible the previous week were recorded as missing data.

Although the individual date of each trap capture was recorded, capture data for the traps were identified by calendar week. During some weeks, inclement weather limited access to the traps on only a few days. When one or more habitat types were completely missing from the data corresponding to a specific week, data from that week were excluded from analysis. Inclement weather resulted in the loss of trapping data during nine weeks of the first study period, and two weeks of the second study period. Thus, data were available for 20 of the 29 wk during the first study period (week of 12 October to week of 16 December, week of 6 January to week of 3 March, and weeks of 28 April and 5 May), and for 28 of the 30 wk during the second study period (week of 15 September to week of 6 October, week of 27 October to week of 6 April). During each of these weeks, each habitat type was represented by ≥28 traps except for the 3 wk beginning 22 December through 5 January of the second study period. During these weeks, we could access only 11 or 12 traps associated with the resaca habitat.

Statistical Analyses. Trap captures during the fallow season of the Lower Rio Grande Valley tend to follow a seasonal pattern (Guerra and Garcia 1982). Thus, for the purpose of analysis, weeks of trap capture were arbitrarily combined into three seasonal periods: fall, winter, and spring. The fall period extended from study period initiation to mid-December. This period was characterized by moderate-to-high air temperatures and relatively high levels of weevil activity. The winter period extended from mid-December to mid-February and typically involved lower temperatures and weevil activity levels than the fall period. The spring period extended from mid-February (the normal time of the earliest planting of cotton in the region) until the end of the study period. Like the fall period, the spring period typically featured higher air temperatures and higher levels of weevil activity than the winter period.

The trapping data were analyzed by mixed-model analysis of variance (ANOVA) (PROC MIXED, SAS Institute 2001). The model contained fixed effects of weevil sex, season, and habitat type, and all possible interactions. Random effects included study period (year of study), and week nested within season and year [week(season*year)]. In addition, random effects of habitat*week(season*year) and sex*habitat* week(season*year) were included as error terms for tests of fixed effects. Because the variances associated with trap captures differed substantially between seasonal periods, the GROUP = SEASON option was included in the RANDOM statement of PROC MIXED. Differences among levels of main effects were identified using Tukey–Kramer adjusted *P* values corresponding to paired comparisons among the least-squares means (adjust = TUKEY option of the LSMEANS statement). The sources of significant interaction terms also were explored using the SLICE option of the LSMEANS statement. Selected differences among levels of effects within statistically significant slices of interactions were further examined using contrasts.

Results and Discussion

Over the course of the experiment, the mean $\pm$ SE number of male weevils captured $trap^{-1} wk^{-1}$ (1.38 $\pm$ 0.289) was similar to the mean number of females captured (1.40 $\pm$ 0.289; $F = 0.34$; df = 1, 315; $P = 0.56$). Neither were there significant interactions between weevil sex and other model effects (sex*season: $F = 0.41$; df = 2, 315; $P = 0.66$; sex*habitat: $F = 0.49$; df = 6, 315; $P = 0.82$; and sex*season*habitat: $F = 0.23$; df = 12, 315; $P > 0.99$). Therefore, influences of other model effects on trap captures were independent of weevil sex.

Significant differences in overall seasonal mean captures of weevils $trap^{-1} week^{-1}$ were not detected (fall: 3.15 $\pm$ 0.842; winter: 0.35 $\pm$ 0.080; spring: 0.68 $\pm$ 0.175; $F = 6.69$; df = 2, 3; $P = 0.08$). Differences among habitat types in the numbers of weevils captured were observed ($F = 11.44$; df = 6, 270; $P < 0.01$), but a significant season*habitat interaction ($F = 3.76$; df = 12, 270; $P < 0.01$) indicated that patterns of trap captures among habitats differed among seasons. Therefore, the respective effects of season and trapping habitat are best illustrated by the patterns in trap captures among combinations of season and habitat.

Comparisons of numbers of captured weevils among habitats within seasonal periods indicated significant differences during each season (fall: $F = 5.96$; df = 6, 270; $P < 0.01$; winter: $F = 8.00$; df = 6, 270; $P < 0.01$; and spring, $F = 18.95$; df = 6, 270; $P < 0.01$). During the fall, captures of weevils tended to be highest in association with the most prominent vegetative features. Mean weekly captures of weevils in traps associated with sugarcane, resaca, and brush habitats were higher than those from canal, fallow, or pasture habitats (Table 1). Captures associated with brush-canals were not different from those from the sugarcane, resaca, or brush habitats and also did not differ from captures associated with canals. The boll weevil

Table 1. Mean ± SE weekly captures of boll weevils in pheromone traps associated with seven habitat types during three seasonal periods in the Lower Rio Grande Valley of Texas

Habitat	Seasonal period[a]		
	Fall	Winter	Spring
Brush	4.38 ± 1.034aA	0.89 ± 0.145aC	1.92 ± 0.228aB
Resaca	4.49 ± 1.031aa	0.51 ± 0.110bB	0.85 ± 0.193bB
Sugarcane	5.01 ± 1.034aA	0.35 ± 0.142bcB	0.59 ± 0.221bcB
Brush-lined canal	3.54 ± 1.030abA	0.37 ± 0.088bB	0.52 ± 0.181cB
Canal	1.81 ± 1.034bcA	0.11 ± 0.135cA	0.23 ± 0.216cdA
Pasture	1.27 ± 1.030cA	0.15 ± 0.092cA	0.44 ± 0.184cA
Fallow field	1.53 ± 1.031cA	0.09 ± 0.105cA	0.19 ± 0.195dA

Means in a column followed by the same lowercase letter, or in a row followed by the same uppercase letter, are not significantly different, $\alpha = 0.05$.

[a] Seasonal periods were defined as fall, early-September to mid-December; winter, mid-December to mid-February; and spring, mid-February to early-May.

commonly reproduces on regrowth cotton in the Lower Rio Grande Valley (Rummel and Summy 1997), and the inability to statistically distinguish the trap captures associated with canals from those of brush-canals was probably caused by the influence of regrowth or volunteer cotton in the fall of the first study period. This cotton occurred primarily in the vicinity of the canals and was producing weevils by the time it was destroyed in late November.

During the winter, captures of weevils were highest in traps associated with the brush habitat (Table 1). Captures associated with other habitats featuring prominent vegetation (resaca and brush-canal) were also higher than those from habitats featuring sparse or only low-growing vegetation (pasture, canal, and fallow). Magnitudes of weevil numbers captured in traps associated with sugarcane could not be statistically distinguished from other habitat types except brush. This intermediate ranking probably resulted from burning and harvest activities that occurred during the latter portion of the winter season and extended into the early portion of the spring season in both study years.

Highest trap captures during the spring period occurred in traps associated with brush, followed by resaca (Table 1). Lowest mean captures occurred in traps associated with canal and fallow habitats. Magnitudes of captures associated with sugarcane, brush-canal, and pasture habitats were intermediate.

Comparisons among seasons within individual habitats indicated that the numbers of weevils captured by traps associated with some habitat types reflected seasonal differences, whereas those associated with other habitats did not. Seasonal differences in weevil captures were not observed for habitat types of canal ($F = 1.41$; df = 2, 270; $P = 0.25$), pasture ($F = 1.52$; df = 2, 270; $P = 0.22$), or fallow ($F = 1.04$; df = 2, 270; $P = 0.35$; Table 1). In contrast, seasonal differences in trap captures were observed for habitat types featuring prominent vegetation (brush-canal: $F = 4.87$; df = 2, 270; $P < 0.01$; brush: $F = 11.97$; df = 2, 270; $P < 0.01$; sugarcane: $F = 10.15$; df = 2, 270; $P < 0.01$; and resaca:

$F = 8.26$; df = 2, 270; $P < 0.01$; Table 1). In each of these habitats, numbers of captured weevils were highest for the fall compared with other seasons. Only traps associated with the brush habitat detected differences in weevil captures between winter and spring. In the traps associated with sugarcane, it is possible that observed seasonal differences in weevil captures were caused or influenced by harvest activities in the late winter and early spring. However, patterns associated with other habitat types suggest the higher captures of weevils in traps associated with prominent vegetative features also provided improved ability to detect seasonal differences in trap response.

Our results demonstrate marked differences in captures of boll weevils by pheromone traps associated with different habitat types. In particular, captures of weevils tended to be highest in association with habitats featuring prominent vegetation irrespective of trapping season. Although our data are restricted to a subtropical population of the boll weevil, D.W.S. has made similar observations in the Brazos Valley of Texas, and this knowledge has been used to minimize the effort required to capture overwintered weevils for other studies (unpublished data). Regardless, mechanisms responsible for our observations are unknown. Moderation of winds by prominent vegetation, as demonstrated by Sappington and Spurgeon (2000a), may have influenced captures of weevils in our study. However, it is likely that factors other than wind moderation also were involved because trap locations were selected without reference to wind direction. The boll weevil is known to exhibit color preferences (Taft et al. 1969, Cross et al. 1976, Leggett and Cross 1978), suggesting the possibility that response to prominent vegetation may have a visual basis. This hypothesis would be consistent with previous observations of increased response to traps placed near wooded areas in both temperate (Cross and Hardee 1968, Hardee et al. 1972, Roach et al. 1972) and subtropical areas (Guerra and Garcia 1982) and offers an explanation in addition to the nearness of traps to overwintering habitat.

Boll weevil eradication programs, and associated maintenance programs, rely primarily on the pheromone trap for population monitoring and detection. In active eradication programs, traps are normally placed in close association with cotton. Although this is not the case in maintenance programs, traps are normally placed without regard for immediate trap surroundings. Our results suggest the potential to improve current trapping protocols through purposeful trap placement. This potential is particularly high in maintenance programs in which trapping activities do not focus primarily on cotton fields. However, such potential is contingent on at least two factors. First, the increased response to traps that we observed should also translate into increased weevil detection efficiency when population levels are very low. Second, because traps assigned to prominent vegetative features in our study were positioned immediately adjacent to the vegetation, it would be useful to better understand the role of trap distance from the vegeta-

tion. Additional studies are currently underway to investigate these spatial aspects of response to traps associated with prominent vegetation.

Acknowledgments

References Cited

Cross, W. H., and D. D. Hardee. 1968. Traps for survey of overwintered boll weevil populations. U.S. Dep. Agric. Coop. Econ. Insect Rep. 18: 430.

Cross, W. H., H. C. Mitchell, and D. D. Hardee. 1976. Boll weevils: response to light sources and colors on traps. Environ. Entomol. 5: 565–571.

El-Lissy, O., F. Myers, R. Frisbie, T. Fuchs, D. Rummel, R. Parker, D. Dipple, E. King, G. Cunningham, F. Carter, et al. 1997. Boll weevil eradication update—Texas, 1996, pp. 973–980. *In* Proceedings of the Beltwide Cotton Conference, National Cotton Council, Memphis, TN.

Graham, H. M., N. S. Hernandez, Jr., J. R. Llanes, and J. A. Tamayo. 1978. Overwintering habits of the boll weevil in the Lower Rio Grande Valley, Texas. Environ. Entomol. 7: 345–348.

Guerra, A. A., and R. D. Garcia. 1982. Seasonal patterns of boll weevil response to grandlure-baited traps in the subtropical Rio Grande Valley of Texas. Southwest Entomol. 7: 216–220.

Hardee, D. D., W. H. Cross, E. B. Mitchell, P. M. Huddleston, and H. C. Mitchell. 1972. Capture of boll weevils in traps baited with males: effect of size, color, location, and height above ground level. Environ. Entomol. 1: 162–166.

Leggett, J. E., and W. H. Cross. 1978. Boll weevils: the relative importance of color and pheromone in orientation and attraction to traps. Environ. Entomol. 7: 4–6.

Roach, S. H., H. R. Agee, and L. Ray. 1972. Influence of position and color of male-baited traps on captures of boll weevil. Environ. Entomol. 1: 530–532.

Rummel, D. R., and K. R. Summy. 1997. Ecology of the boll weevil in the United States cottonbelt. Southwest. Entomol. 22: 356–376.

Sappington, T. W., and D. W. Spurgeon. 2000a. Variation in boll weevil (Coleoptera: Curculionidae) captures in pheromone traps arising from wind speed moderation by brush lines. Environ. Entomol. 29: 807–814.

Sappington, T. W., and D. W. Spurgeon. 2000b. Preferred technique for adult sex determination of the boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 93: 610–615.

SAS Institute. 2001. SAS/STAT user's guide, release 8.02 ed. SAS Institute, Cary, NC.

Smith, J. W. 1998. Boll weevil eradication: area-wide pest management. Ann. Entomol. Soc. Am. 91: 239–247.

Taft, H. M., A. R. Hopkins, and H. R. Agee. 1969. Response of overwintered boll weevils to reflected light, odor, and electromagnetic radiation. J. Econ. Entomol. 62: 419–424.